

**CLAIMS:**

1. A switching method for selectively directing an input beam to at least one of two output channels, the method comprising the steps of:

- 5 (i) providing incidence of the input beam onto a polarizing beam splitting surface to thereby enable splitting of the input beam into two beam components of different polarizations propagating along different optical paths;
- 10 (ii) passing the input beam components of different polarizations through a controllable polarization rotating medium operable to selectively affect the polarization of each of the beam components; and
- 15 (iii) directing the beam components that have passed through the polarization rotating medium onto said polarizing surface, thereby producing at least one output beam propagating towards at least one selected output channel, depending on a current mode of the said medium.

2. The method according to Claim 1, wherein the input beam passes through the controllable polarization rotating medium prior to being split into said two beam components of different linear polarization states.

20 3. The method according to Claim 1, wherein steps (i) - (iii) are repeated with respect to said at least one output beam by directing it towards an additional polarizing beam splitting surface, and passing split beam components of said at least one output beam through an additional controllable polarization rotating medium capable of affecting polarizations of the split beam components, and an additional  
25 beam directing means that directs the beam components onto said additional polarizing beam splitting surface, thereby producing at least one additional output beam propagating towards a selected additional output channel.

4. The method according to Claim 1, wherein the input beam is directed towards first and second output channels, the method comprising the steps of:

- operating said controllable polarization rotating medium to be in its operative mode, in which it affects the polarizations of said beam components, thereby producing two output beams;
- repeating steps (i) - (iii) with respect to each of said two output beams, by performing the steps of:
  - directing the first output beam towards a first additional polarizing beam splitting surface, passing split beam components of said first output beam through a first additional controllable polarization rotating medium capable of affecting polarizations of the split beam components, when in an operative mode of said medium and not affecting polarizations of the split beam components, when in an inoperative mode of said medium, and directing the beam components passed through the first additional medium to a first additional beam directing means that directs the beam components onto said first additional polarizing beam splitting surface, to thereby produce two output beams propagating towards the first output channel and a blocked output channel, respectively;
  - directing the second output beam towards a second additional polarizing beam splitting surface, passing split beam components of said second output beam through a second additional controllable polarization rotating medium capable of affecting polarizations of the split beam components, when in an operative mode of said medium and not affecting polarizations of the split beam components, when in an inoperative mode of said medium, and directing the beam components passed through the second additional medium to a second additional beam directing means that directs the beam components onto said second additional polarizing beam splitting surface, to thereby produce two output beams propagating towards the second output channel and a blocked output channel, respectively;

the method thereby enabling to reduce crosstalk between the two output channels.

5. The method according to Claim 4, and also comprising the steps of operating the controllable polarization rotating media to provide polarization rotation of the beam components passing therethrough to a degree other than  $90^\circ$ , the method thereby enabling to increase a switching speed.
- 5 6. The method according to Claim 1, and also comprising the step of passing at least one of the split beam components of the input beam through an optical filtering means accommodated in the optical path of said at least one split beam component, thereby enabling to filter light that has interacted with the polarizing beam splitting surface to correct for an error introduced by the polarizing beam splitting surface.
- 10 7. The method according to Claim 6, wherein the split beam component passing through the filtering means is a beam component reflected from the polarizing beam splitting surface, said filtering means comprising an additional polarizing beam splitting surface, light reflected from said additional polarizing beam splitting surface propagating towards the controllable polarization rotating medium.
- 15 8. The method according to Claim 6, wherein the split beam component passing through the filtering means is a beam component transmitted through said polarizing beam splitting surface, said filtering means comprising a polarization rotating element capable of  $90^\circ$ -rotating the polarization of the incident beam component, and a polarizing beam splitting surface, light passed through said  
20 polarization rotating element and reflected from said additional polarizing beam splitting surface propagating towards said controllable polarization rotating medium.
9. The method according to Claim 1, and also comprising the step of providing incidence of said split beam components of the input beam onto said medium with a certain incidence angle.
- 25 10. The method according to Claim 1, wherein said medium is operated to provide a desired difference in phase delay in a range  $0-\lambda/2$  between two principal axes of said medium, thereby enabling to obtain desirable partition between the two output channels.
11. The method according to Claim 1, used for multicast switching.

12. The method according to Claim 1, wherein said medium is operated to provide a desired difference in phase delay in a range  $0-\lambda/2$  between two principal axes of said medium, one of the output channels being blocked, thereby enabling variable attenuating.
- 5 13. The method according to Claim 1, wherein an electrostatic field applied to said medium is selected such as to compensate for a hysteresis phenomenon occurring in said medium.
14. The method according to Claim 1, wherein an electrostatic field applied to said medium is selected so as to fit phases of the beam components passing  
10 therethrough, thereby compensating for a phase shift caused by beam reflection effects during the beam propagation.
15. The method according to Claim 1, wherein an electrostatic field applied to said medium is such as to cause a difference of  $\lambda/2$  in phase delay between the split beam components of different polarizations, the method thereby enabling to reduce  
15 switching differential voltage requirements.
16. An all-optical switch device for selectively directing an input beam to at least one of two output channels, the device comprising:
- (a) a polarizing beam splitting surface capable of splitting an input beam into two beam components of different polarizations and directing the split beam  
20 components to propagate along different optical paths, and capable of combining two beam components of different polarizations to produce at least one output beam;
  - (b) a controllable polarization rotating medium accommodated in optical paths of the input beam components, and selectively operable to affect the polarization  
25 thereof; and
  - (c) beam directing means accommodated in optical path of the beam components passed through the polarization rotating medium for directing the beam components onto said polarizing beam splitting surface to thereby produce at least one output beam propagating towards at least one selected output channel.

17. The device according to Claim 16, wherein said medium is of a kind based on an electro-optic effect.
18. The device according to Claim 17, wherein said electro-optic effect is a linear effect.
- 5 19. The device according to Claim 18, wherein said medium is made of ferroelectric crystals.
20. The device according to Claim 19, wherein said ferroelectric crystal is lithium niobate ( $\text{LiNbO}_3$ ).
21. The device according to Claim 17, wherein said electro-optic effect is a  
10 quadratic effect.
22. The device according to Claim 21, wherein said medium is made of ceramics.
23. The device according to Claim 22, wherein said ceramics is Lead Lanthanum Zirconate Titanate (PLZT).
- 15 24. The device according to Claim 16, wherein said medium is made of a liquid crystal (LC) material.
25. The device according to Claim 16, operating as one of the following switches:  $1 \times 2$ ,  $2 \times 1$ , and  $2 \times 2$ .
26. The device according to Claim 16, wherein the controllable polarization  
20 rotating medium comprises two elements made of a polarization rotating material, and said beam directing means comprises two retro-reflective elements associated with said two polarization rotating elements, respectively, so as to reflect the beam components of different polarizations of the input beam towards the polarization rotating elements, and reflect the beams passed through the polarization rotating  
25 elements onto said polarizing beam splitting surface.
27. The device according to Claim 26, wherein said two polarization rotating elements and beam directing elements associated therewith are accommodated at opposite sides of said polarizing surface, respectively.
28. The device according to Claim 27, wherein said polarizing beam splitting  
30 surface is a surface of a polarizing beam splitter made of a controllable polarization

rotating material, said two polarization rotating elements being presented by two halves of the beam splitter at the opposite sides of the polarizing beam splitting surface.

29. The device according to Claim 28, wherein said two beam directing  
5 elements are formed by reflective surfaces of the polarizing beam splitter.

30. The device according to Claim 26, wherein each of the two beam directing elements is in the form of a two-part mirror, the corresponding one of the polarization rotating element being accommodated in a space between the two parts of the respective beam directing element.

10 31. The device according to Claim 16, wherein the beam directing means is at least partly incorporated within the controllable polarization rotating medium.

32. The device according to Claim 31, wherein the controllable polarization rotating medium comprises two elements made of a polarization rotating material, and said beam directing means comprises two retro-reflective elements associated  
15 with said two polarization rotating elements, respectively, so as to reflect the beam components of different polarizations of the input beam towards the polarization rotating elements, and reflect the beams passed through the polarization rotating elements onto said polarizing beam splitting surface.

33. The device according to Claim 32, wherein said two beam directing  
20 elements comprises surfaces of two polarization rotating elements, respectively.

34. The device according to Claim 33, wherein the two polarization rotating elements are in the form of two corner prisms, respectively, having reflective inner surfaces, the corner prisms thereby serving as both the polarization rotating and the beam directing means.

25 35. The device according to Claim 33, wherein the two polarization rotating elements are in the form of two penta-like prisms, respectively, having reflective inner surfaces, the corner prisms thereby serving as both the polarization rotating and the beam directing means.

36. The device according to Claim 32, wherein said two beam directing elements are formed by inner surfaces of two substantially V-shaped structures, respectively, made of the polarization rotating material.

37. The device according to Claim 26, wherein said polarizing beam splitting surface is a surface of a polarizing beam splitter cube, which has two pairs of reflective surfaces shaped as two-part right-angle prisms defining two groove-like spaces, said two beam directing elements being presented by said reflective surfaces of the beam splitter, each of said two polarization rotating elements being accommodated inside the beam splitter within said groove-like spaces, respectively.

38. The device according to Claim 31, wherein said polarizing beam splitting surface is a surface of a polarizing beam splitter cube, which has three truncated corners forming three locally adjacent facets, such that the intermediate facet intercepts with a plane of said polarizing beam splitting surface, said polarization rotating means being in the form of two plates made of a polarization rotating material accommodated at the other two facets of the beam splitter, said beam directing means being formed by two reflective surfaces of said plates and a reflective surface of the intermediate facet, said reflective surfaces of the plates being rear surfaces with respect to the directions of beam propagation to the plates.

39. The device according to Claim 16, wherein said polarizing beam splitting surface is a surface of a polarizing cubic beam splitter, which has three truncated corners forming three locally adjacent facets, such that the intermediate facet intercepts with a plane of said polarizing beam splitting surface, said polarization rotating means being in the form of a plate accommodated at the intermediate facet outside of the beam splitter and having a reflective surface, said beam directing means being formed by said reflective surface of the plate and reflective surfaces of the other two facets.

40. The device according to Claim 16, wherein said polarizing beam splitting surface is a surface of a polarizing beam splitter cube, said beam directing means including reflective surfaces of the polarizing beam splitter.

41. The device according to Claim 16, wherein said beam directing means are also accommodated in the optical path of the split beam components of the input beam to direct said beam components to the polarization rotating means.

42. The device according to Claim 16, and also comprising optical filtering  
5 means accommodated in the optical path of at least one of the split beam components propagating towards the controllable polarization rotating medium, thereby enabling to filter light passed through the polarizing beam splitting surface to correct for an error introduced by the polarizing beam splitting surface.

43. The device according to Claim 42, wherein the filtering means is  
10 accommodated in the optical path of the split beam component reflected from the polarizing beam splitting surface, said filtering means comprising an additional polarizing beam splitting surface, light reflected from said additional polarizing beam splitting surface reaching the controllable polarization rotating medium.

44. The device according to Claim 42, wherein the filtering means is  
15 accommodated in the optical path of the split beam component transmitted through said polarizing beam splitting surface, said filtering means comprising a polarization rotating element capable of 90°-rotating the polarization of the incident beam component, and a polarizing beam splitting surface, light passed through said polarization rotating element and reflected from said additional polarizing beam  
20 splitting surface propagating towards said controllable polarization rotating medium.

45. An all-optical device operable for selectively directing an input beam to at least one of two output channels, the device comprising a beam splitter made of a controllable polarization rotating material shiftable between its inoperative mode, in which it does not affect polarization of a beam passing therethrough, and an operative  
25 state thereof, in which it affects polarization of a beam passing therethrough, the beam splitter having a polarizing beam splitting surface and reflective surfaces at opposite sides of said polarizing beam splitting surface, said polarizing beam splitting surface being capable of splitting a non-polarized input beam into two beam components of different polarizations and directing the split beam components to  
30 propagate along different optical paths towards the corresponding reflective surfaces,



and capable of combining beam components of different polarization states, directed onto said polarizing beam splitting surface by the reflective surfaces, thereby producing at least one output beam propagating towards the at least one selected output channel.

46. The device according to Claim 45, operating as one of the following switches:  $1 \times 2$ ,  $2 \times 1$ , and  $2 \times 2$ .

47. A multi-stage all-optical switch structure comprising at least two switch devices, each constructed according to Claim 16, the structure thereby operating as one of the following switches:  $1 \times n$ ,  $2 \times n$ , ...,  $m \times n$ .

48. A multi-stage all-optical switch structure comprising an array of at least first and second switch devices each comprising:

(i) an array of at least first and second switch devices, each comprising:

(a) a polarizing beam splitting surface capable of splitting an input beam into two beam components of different polarizations, and directing said two beam components to propagate along different optical paths, and capable of combining two beam components of different polarization states into at least one output beam;

(b) a controllable polarization rotating means accommodated in optical paths of the two input beam components, and selectively operable to affect the polarization of each of the beam components; and

(c) beam directing means accommodated in optical path of the beam components passed through the polarization rotating means for directing the beam components of different linear polarization states onto said polarizing beam splitting surface so as to produce the at least one output beam propagating towards at least one selected output channel; and

(ii) at least one beam directing element accommodated in an optical path of the output beam produced by the first switch device to direct said output beam onto a polarizing beam splitting surface of the second switch device.

49. A switching method for reducing crosstalk between output channels of a switching structure where output light signals are collected, the method utilizing

beam propagation through the switching structure composed of three switch devices, each constructed as device of Claim 16 and having two output channels, wherein the two output channels of the first switch device are two input channels of, respectively, the second and the third switch devices, one of the output channels of the second switch device and one of the output channels of the third switch device being blocked to prevent light output therethrough, light signals collected at unblocked output channels of the second and third switch devices being thereby characterized by reduced crosstalk.

50. A switching method for increasing a switching speed utilizing beam propagation through a switching structure composed of three switch devices, each constructed as device of Claim 16 and having two output channels, wherein

- the two output channels of the first switch device are two input channels of, respectively, the second and the third switch devices, one of the output channels of the second switch device and one of the output channels of the third switch device being blocked to prevent light output therethrough, light signals being collected at unblocked output channels of the second and third switch devices;
- the controllable polarization rotating medium of each of the three switch device is operable to rotate the polarizations of the beam components passing therethrough at an angle other than 90 degree.

51. The switching method for directing an input beam towards two output channels with a desired energy partition between the two output channels, the method utilizing light propagation through a switch device constructed according to Claim 16, wherein said medium is operated to provide a desired difference in phase delay in a range  $0-\lambda/2$  between two principal axes of said medium.

52. A switching method for directing an input beam towards a selected one of two output channels with the other output channel being blocked, to thereby enable variable energy attenuating, the method utilizing light propagation through the switch device constructed according to Claim 16, wherein said medium is operated to

provide a desired difference in phase delay in a range  $0-\lambda/2$  between two principal axes of said medium.

53. A switching method for directing an input beam towards at least one output channel, the method utilizing light propagation through the switch device constructed according to Claim 16, wherein operation of said controllable polarization rotating medium is appropriately controlled to compensate for a hysteresis phenomenon occurring in said medium.

54. A switching method for directing an input beam towards at least one output channel in a manner to reduce switching differential voltage requirements, the method utilizing the switch device constructed according to Claim 16, wherein operation of said controllable polarization rotating medium is appropriately controlled such as to cause a difference of  $\lambda/2$  in phase delay between the split beam components of different polarizations.

55. A method for splitting an unpolarized input beam into two output beam components of different polarizations, the method comprising the steps of:

- directing the input beam onto a first polarizing beam splitting surface, thereby obtaining two beam components of different polarizations, which are, respectively, reflected from and transmitted through said first polarizing splitting surface;
- 20 - directing at least one of the beam components, which have interacted with said first polarizing beam splitting surface, onto a filtering means comprising a second polarizing beam splitting surface, thereby enabling to filter light interacting with said second polarizing beam splitting surface to correct for an error introduced by the first polarizing beam splitting surface.